SH 4.2-18

THE EFFECT OF THE NEUTRAL SHEET STRUCTURE OF THE INTERPLANETARY MAGNETIC FIELD ON COSMIC RAY DISTRIBUTION IN SPACE

Alania M.V., Aslamazashvili R.G., Bochorishvili T.B., Djapiashvili T.V., Tkemaladze V.S.

The Institute of Geophysics, Georgian Academy of Science, Z.Rukhadze str.1, 380093, Tbilisi

ABSTRACT

I.The results of the numerical solution of the anisotropic diffusion equation are presented in the paper. It is shown that the modulation depth of galactic cosmic rays is defined by degree of curvature of the neutral current sheet in Heliosphere. 2.The effect of the regular interplanetary magnetic field (IMF) on cosmic ray anisotropy in the epoch of solar activity minimum (in 1976) is analysed by the data of the neutron super-monitors of the world network and the heliolatitudinal gradient and cosmic ray diffusion coefficient are defined.

<u>The theoretical model.</u> The recent investigations/1,2/ show that the neutral current sheet changes its range significantly for 11-year period of the Sun's cycle and can be one of the reasons of cosmic ray modulation. Really, the curvatures of the interplanetary magnetic field lines of forces(IMF) correspond to the waved structure of the neutral sheet that is identical with the appearance of high-value zenithal component of IMF, Hz. The experimental observations in space show that Hz component of IMF is, in the mean, a high value $\sim 2\ 10^{-9}\ nT$ /3/ and therefore, its account in solution of comic ray anisotropic diffusion equation is of necessity.

The anisotropic diffusion equation /4/ for the stationary case is used:

$$\nabla_i(\varkappa_{ik}\nabla_k n)-\nabla_i(n\,u_i)+\frac{1}{3R^2}\frac{\partial}{\partial R}(R^3 n)\nabla_i u_i=0 \tag{1}$$

where $\varkappa_{ik}$ -the tensor coefficients of diffusion, n and R -the density and the rigidity of the particle, and u_i -solar wind velocity. It is suggested in equation solution (1) that the radius of the modulation volume is 50 a.u., u=4.10⁷cm/s, the diffusion coefficient along the magnetic field has the form

$$\varkappa_{\parallel}=\varkappa_0\, EXP(R_1/R)\cdot(R_2+R)^2\,\varphi(\theta)\cdot\phi(r) \tag{2}$$

where $\varkappa_0 = 10^{22}\,cm^2/sec$, R_1 =0,05GV, R_2=3GV, $\varphi(\theta)$ is changed in the range I-5 from the helioequator to the near-polar region, and $\phi(r)=1+\alpha(r/r_0)$, where α =0,I, r_0 -modulation region radius.

The range of the waved structure of the neutral current sheet is given in the form

$$\gamma = A\gamma_0 (r/r_0) \cos(16\pi r/r_0) \qquad (3)$$

A and γ_0 are chosen so that the neutal current sheet on the Earth's orbit (r_E=I,5·IO^{13} cm) is at the heliolatitude IO^o . In this case $A=5$ and γ =10^o.

The equation (1) is solved by the net method for the two dimensional case (r, θ) $\frac{\partial n}{\partial \varphi} = \frac{\partial^2 n}{\partial \varphi^2} = 0$ and the results are presented in Fig. la,b. The curve (a) shows the change of the relative density of IO Gev energy cosmic rays, when the curvature (3) is defined by the parameter A =0,5, i.e. the maximum removal of the neutral sheet from the equator of the Sun on the Earth's orbit is L=2,5 ·IO^{12} cm.The curve(b) shows the case, when $A=0$ and $L=0$. It is seen that, really, with the increase of neutral current sheet range, the significant cosmic ray modulation is expected, which by its value is compared with the amplitude of 11-year variation in the energy region IO-20Gev.

The experimental data on cosmic ray anisotropy.

~~It has been shown in our previous paper /5/~~ that the particle drift effect at the expense of the gradient and the curvature of the interplanetary magnetic field (IMF) is revealed singlevaluedly, especially in the epoch of solar activity minimum. It is known that the particle drift effect in distribution of cosmic ray density and anisotropy can be calculated with the antisymmetric part of the anisotropic diffusion tensor /6/, but , in our opinion, this problem is not always clear, and therefore, sometimes the incorrect interpretation is made. E.g. as it has been done in the report /7/ while reviewing paper /5/, where the epoch of solar activity minimum I965- has been considered.

Four neutron super-monitor stations: Kiel,Norikura, Lomnitsky Stif and Khafelakar have been chosen for revealing the effect of the particle drift in cosmic ray anisotropy (I976). The data of these stations were free from the trends with the periods more than 24 hours and the harmonic coefficients A_1 and B_1 for every day were defined.Then they were averaged depending on the Earth's location in "+" and "-" sectors of IMF.("+" corresponds to the direction of the magnetic lines of forces from the Sun, and "-" toward the Sun). Then, the values A_r and A_φ have been defined in cosmic space taking into account the drift into the Earth's magnetic field and the coupling coefficients /8/ and the means by all four stations were found. The results are presented in Fig.2, where the solid vectors correspond to the theoretical results, and the dashed ones- the experimental data of observation.

It can be seen that a good accord is existed there.

Having the values A_r and A_φ for "+" and "-" sectors of IMF the algebraic equations have been constituted of the form:

$$A_r^{\pm} = \varkappa_{rr}\frac{\partial n}{\partial r} \pm \varkappa_{r\theta}\frac{\partial n}{\partial \theta} - 1{,}5\,U\cdot B\ ; \qquad A_\varphi^{\pm} = \varkappa_{\varphi r}\frac{\partial n}{\partial r} \pm \varkappa_{\varphi\theta}\frac{\partial n}{\partial \theta} \tag{4}$$

Solving the system of equations (4) the mean solar wind velocity is found, and the retious $\alpha = \varkappa_\perp/\varkappa_{\parallel}$ and $\alpha_1 = \varkappa_H/\varkappa_{\parallel}$ are estimated. ($\varkappa_\perp$, $\varkappa_H$ and $\varkappa_{\parallel}$ -the transversal, Hall and parallel diffusion coefficients) and the heliolatitudinal gradient and the diffusion coefficient are estimated.

Discussion and conclusion

I. The degree of curvature of the IMF neutral layer influences appreciably cosmic ray modulation. The modulation depth is large during the extend of the waved neutron layer and can be compared with the amplitude of 11-year variation in the energy region IO-20 Gev.

2. The particle drift effect at the expense of the gradient and the curvature of IMF is revealed singlevaluedly in Cosmic ray anisotropy in the epoch of solar activity minimum in I976.

3. The inverse problem is solved by the equation (4). The solar wind velocity U=455km/s (the direct observations by /9/ give U=450) and ratio α of the transverse diffusion coefficient $\varkappa_\perp$ to the parallel one $\varkappa_{\parallel}$ (α = 0,3) are defined.

It is of interest to note that the same value has been obtained for I965 too.

4. The heliolatitudinal gradient and the diffusion coefficient have been estimated from (4) with the given radial gradient of cosmic rays $\nabla_r n$=(1-2) % / a.u. constituting

$$\nabla_\theta n = (0{,}2-0{,}4)\,\%/a.u.\ , \quad \varkappa_{\parallel} = (0{,}6-1{,}3)\,10^{23}\,cm^2/s$$

respectively.

REFERENCES

I. Hoeksema J.T., Wilcox S.M. and Scherrer P.H., SUIPR, Report №924, Stanford, California, I982.
2. Thomas B.T. and Goldstein B.E., Solar Wind Five, NASA, p.44, I982.
3. Slavin J.A. and Smith E.L., Solar Wind Five, NASA, p.323, I982.
4. Dorman L.T. "Astrophizicheskie aspekti cosmicheskikh Luchei"."Nauka", M.I975.
5. Alania M.V. et al., I8th ICRC, Bangalore, India,L.P., Vol.IO, pp.9I, I983.
6. Jokipii J.R., Levy E.H. and Hubbard W.B., Astr.J., 2I3, 864-868, I977.
7. Jones F.G., I8th ICRC, Bangalore, India.Invited and Rapporteur Papers, Vol.I2., p.379, I983.
8. Nagashima K. et al., Coup.Coef. of Cosmic Rays,Nagoya, Japan, I982.

9. King J.H. Interplanetary Medium Data Bock, NSSDC/WDC-A, I977.
IO. Webber W.R. and Lockwood J.A., I8th ICRC, Bangalore, India, L.p., Vol.IO, p.22, I983.

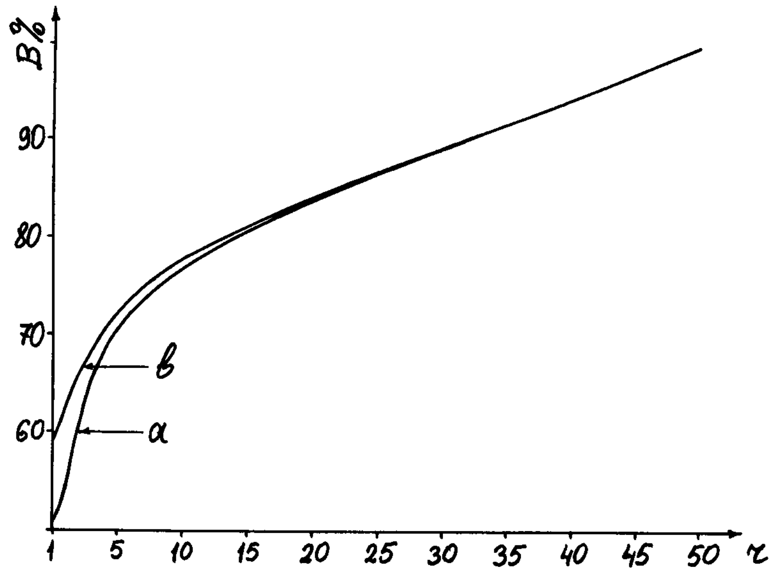

Fig. 1.

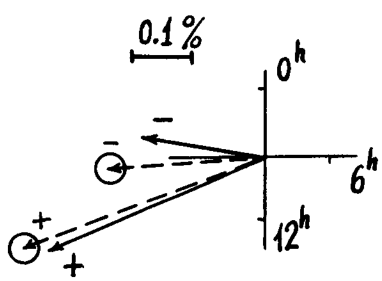

Fig. 2.

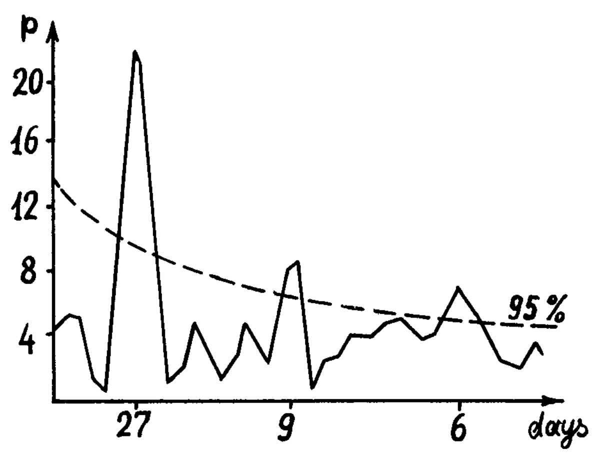

Fig. 3.